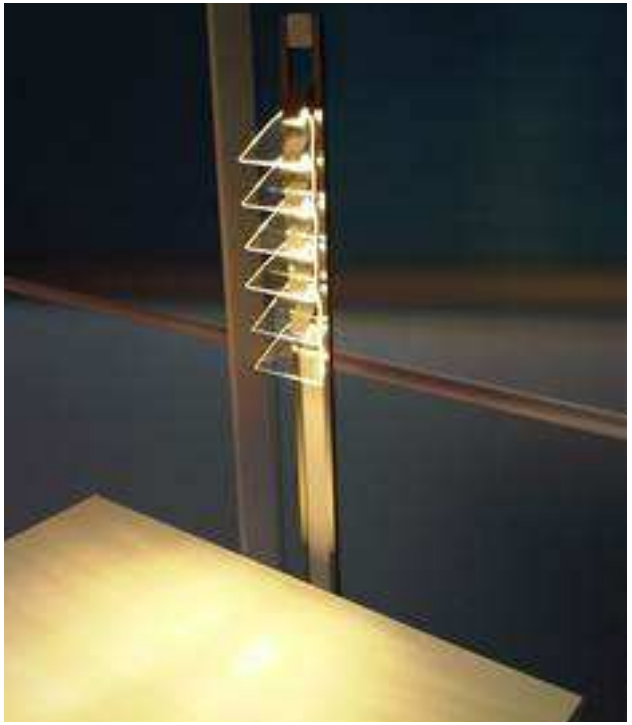
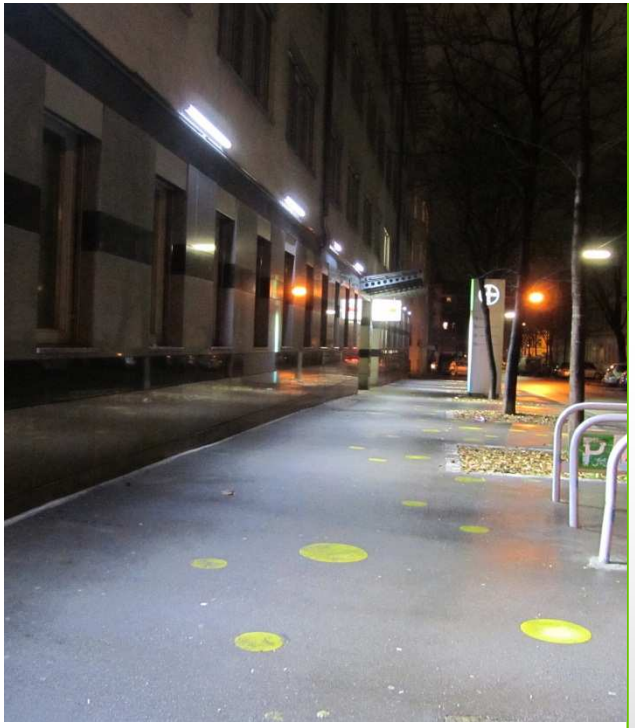




Science For A Better Life

The World of LEDs - How Thermoplastics can support the efficiency of luminaires

Hochschule Hamm Lippstadt, 14. April 2014

Dr. Klaus S. Reinartz, Director Marketing LED EMLA

Bayer MaterialScience AG, 51368 Leverkusen, Deutschland

Our planet from the universe

20% of the electrical power is consumed by general lighting – the demand will increase by 80% until 2030 (acc. to UNEP, 2009)

Sustainable and Ecological Lighting

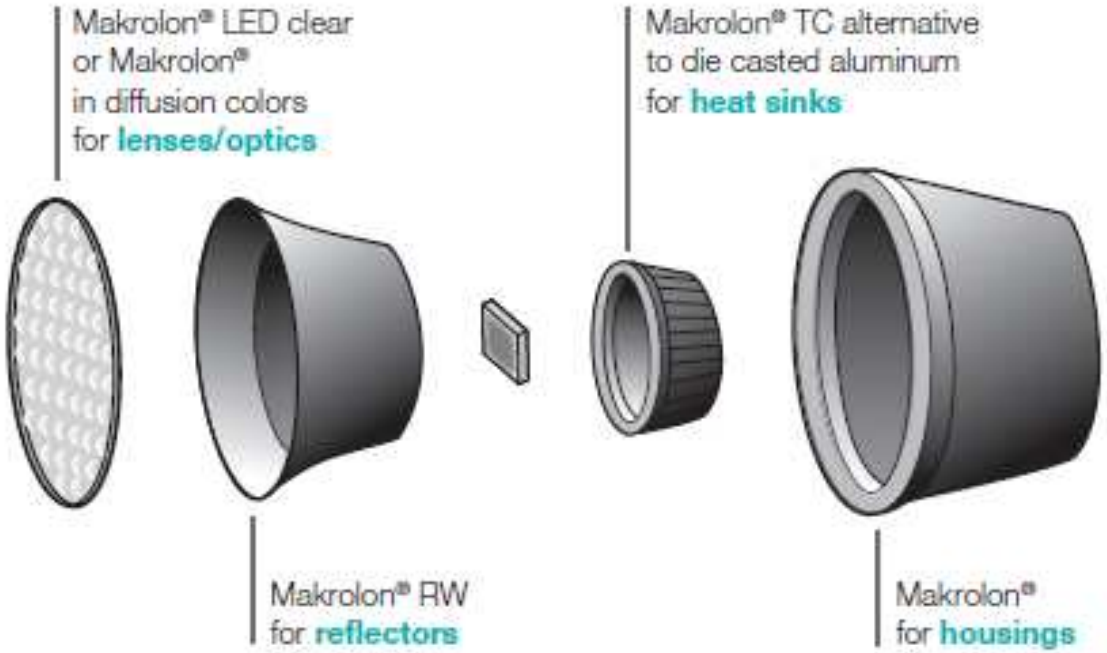
Saving energy and money with LED as light source

Advantages of LED light:

- Lower energy costs
- Much longer lifetime
- Environmentally sound
- Excellent performance

Main Components of a LED based Luminaire

Makrolon® (polycarbonate) can be used for several LED applications

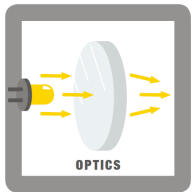


Secondary Optics

Clear Makrolon® LED grades

Advantages of clear Makrolon® LED grades:

- High light transmission over a broad range of wavelengths
- Excellent long-term heat and high flux stability
- High mechanical stability
- Inherently good flame resistance
- Exceptional purity to optimize light transmission



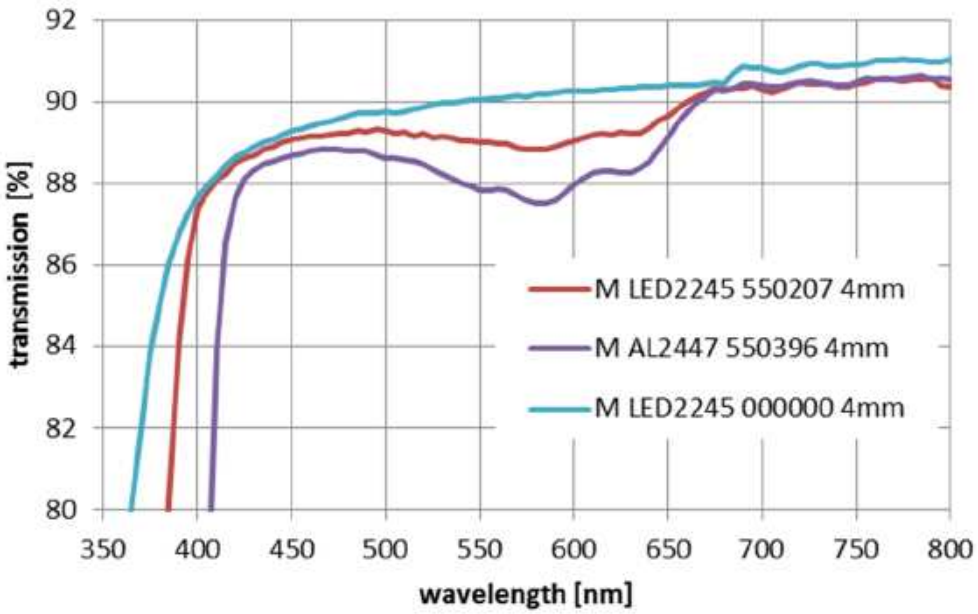
Secondary Optics

Makrolon® LED grades for a long-term performance

Makrolon grade	Color number	MVR (cm3/10min)	Transmission (%@2mm)	UV stabilized
LED2045	000000	61	91	No
LED2245	000000	36	90	No
LED2245	550207	36	89	No
LED2247	550207	36	89	Yes
LED2643	550115	13	89	Yes
AL2447	550396	19	89	Yes

Secondary Optics

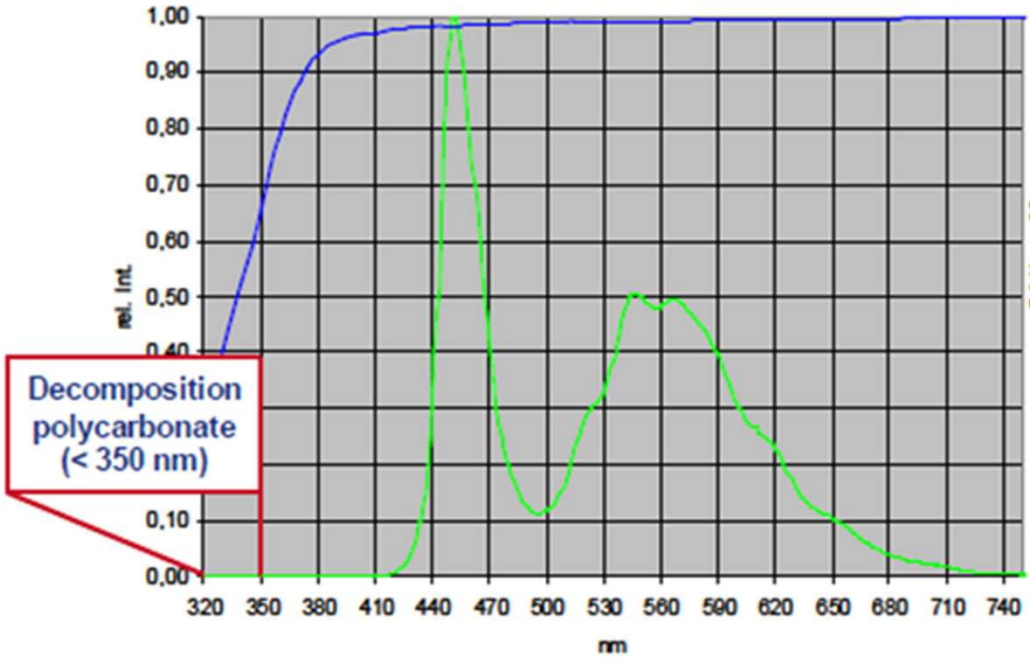
Transmission of selected Makrolon® grades @4mm



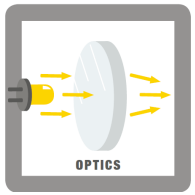
- Makrolon® LED2245 000000 has the highest transmission but has a slightly yellowish appearance
- Makrolon® AL2447 550115 has a crystal clear appearance, but transmission for thick parts is not sufficient
- Makrolon® LED2245 550207:
  - High transmission (>89%@4mm)
  - No UV absorber
  - Ice color with high transmission
  - LED stabilization package
  - Highest purity level

Secondary Optics

Transmission of Makrolon® grades versus LED emission spectrum



- White LEDs show a peak in the blue light around 430 to 460nm
- At the wavelength of the blue peak of the LED the transmission of Makrolon® is still very high
- The absorption of light energy by Makrolon® strongly increases in the range below 400nm
- Blue / white LEDs do not emit light in the range of 400nm or below
- Light above 500nm is absorbed by Makrolon if the material does not contain colorants; any absorption is solely caused by the additive



Secondary Optics

Makrolon® LED grades for a long-term performance

LED optics molded from Makrolon® LED2245

LED optics molded from Makrolon® LED2643

Makrolon® LED2245 natural

Light Guides

Clear Makrolon® LED grades

Advantages of clear Makrolon® grades for light guides:

- High light transmission over a broad range of wavelengths
- Excellent long-term heat and high flux stability
- High mechanical stability
- Inherent flame retardance
- Exceptional purity to optimize light transmission

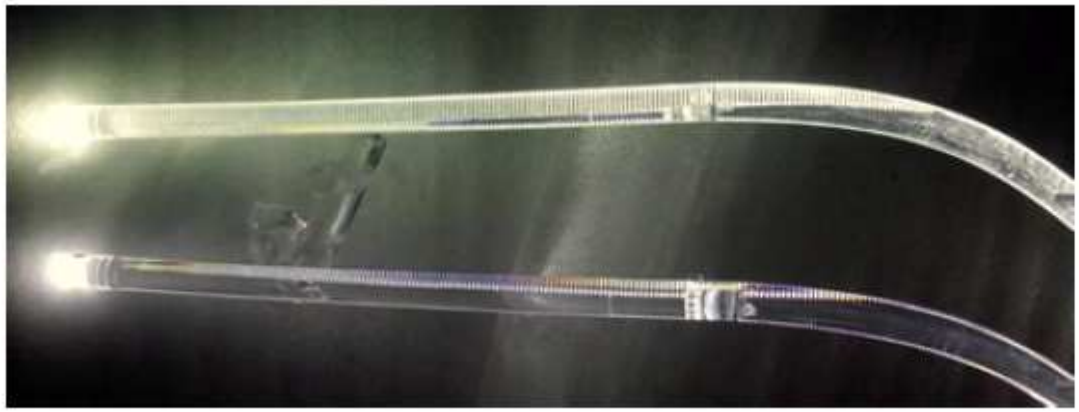
Light Guides

Makrolon® grades with a very high light transmission

Makrolon® grade	Color number	MVR (cm3/10min)	Transmission (%@2mm)	UV stabilized
LED2045	000000	61	91	No
LED2245	000000	36	90	No
LED2245	550207	36	89	No

Light Guides

Makrolon® grades made for special requirements of light guides



Makrolon® LED2245

Color 000000

Color 550207 icecolor

For light guides Makrolon® has to fulfil special requirements:

- Transmission and extinction have to watched carefully due to long pathways
- Thermal stability has to be very high over a long period of time to avoid changes in light transmission
- Dispersion of the refractive index over temperature needs to be low
- High stability against LED light is needed to avoid loss of transmission

Diffusors

Diffusive Makrolon® grades to achieve an even light distribution

Advantages of Makrolon® grades for light diffusion:

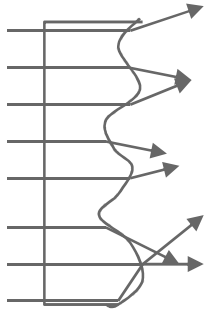
- High light transmission
- High half-power angle
- Strong hiding power of LED light source
- Diffusion products and colors adjusted to your requirements

Mechanisms of Light Diffusion

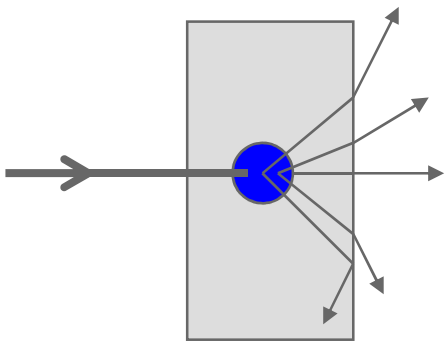
Refraction and Scattering

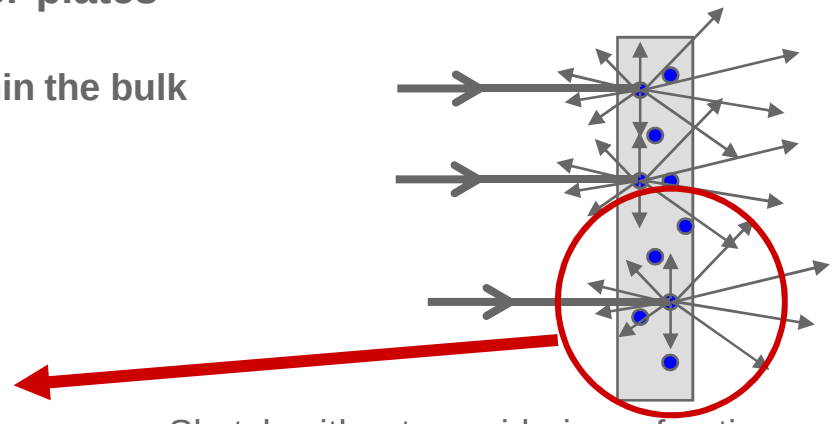
Technique:

- **Refraction** → **surface diffuser plates**
  - ↳ **Frosted glass with irregular structured surface (grain size: ca. 10 µm)**



- **Scattering** → **bulk diffuser plates**
  - ↳ **Scattering objects within the bulk (opal glas plates)**

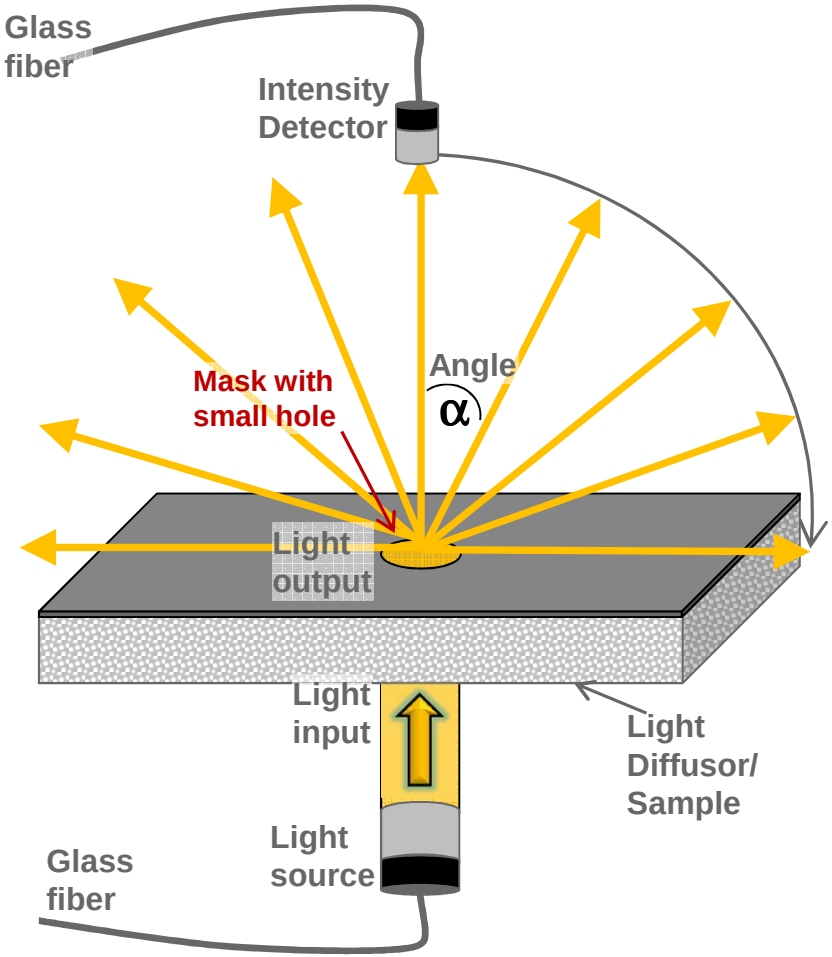




Sketch without considering refraction on the plate surface!

Characterization of a Diffusor Sheet

Measuring the diffusion properties with a single beam



Advantages:

- Single method to compare materials
- Relatively quick measurement

Disadvantages:

- Method may deliver different results if different apparatuses are used
- Single beam measurements do not represent the performance in the real luminaire due to not measuring back-reflection

Recommendation

- Material comparison should always be done on the same machine using the same setup
- Final assessment of different materials should always be done in the final luminaire

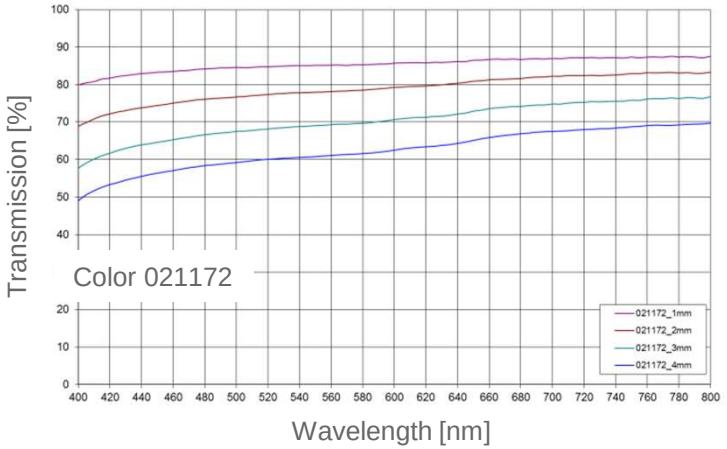
Typical Translucent Makrolon® Grades

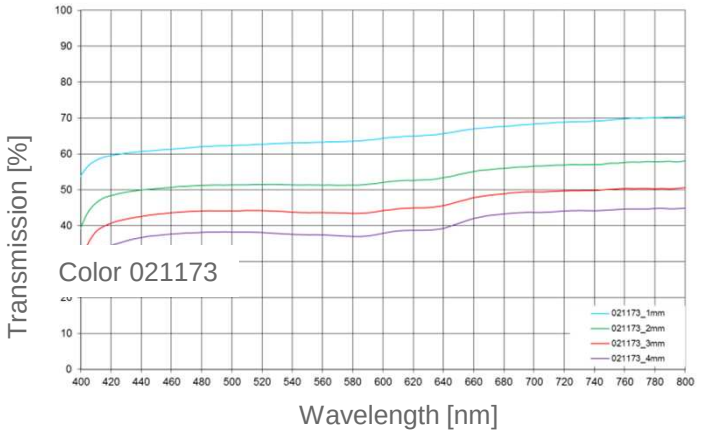
Makrolon® grade	Color number	MVR (cm3/10min)	Transmission (%@2mm)	Half Power Angle (°@2mm)
2407	021180	19	83	4
2407	021172	19	77	22
2407	021182	19	57	50
2407	021173	19	52	57

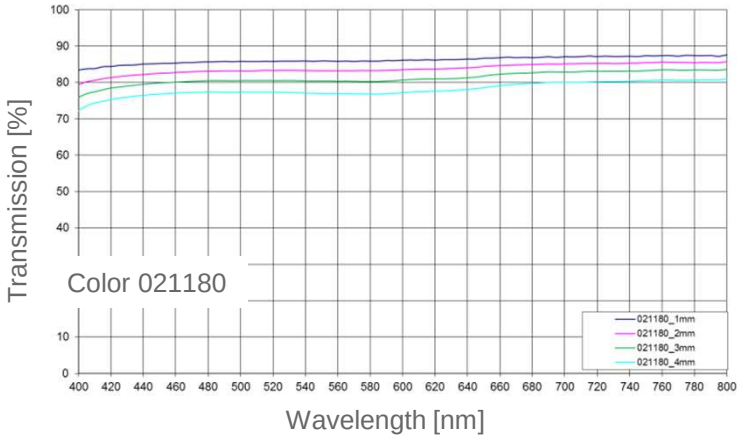
* All properties are shown in intensity related quantities, not with cosine corrected "luminosity" values! The result may be influenced by the individual measurement setup

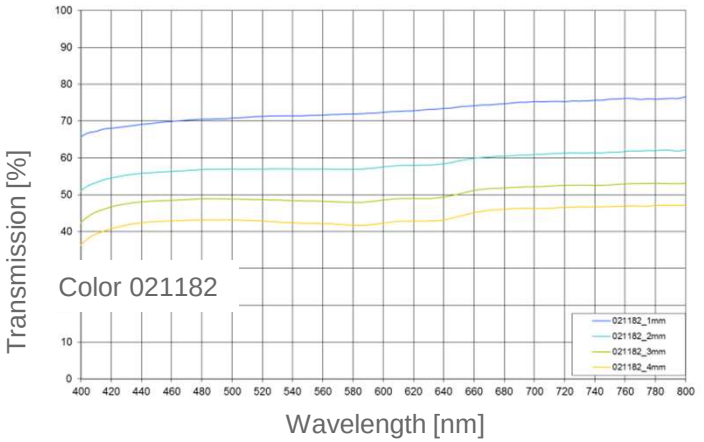
Typical Translucent Makrolon® Colors

Transmission vs. wavelength



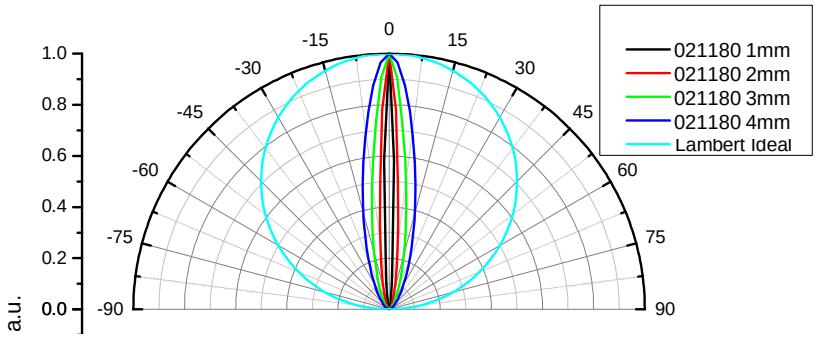


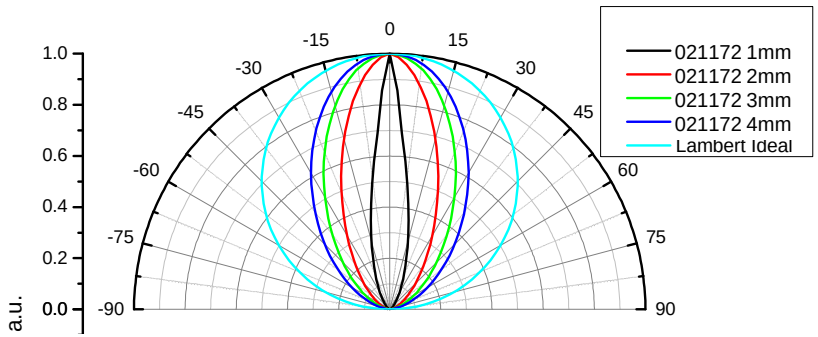


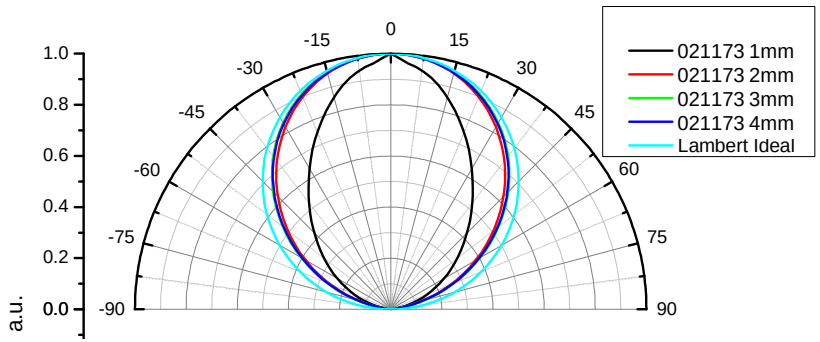


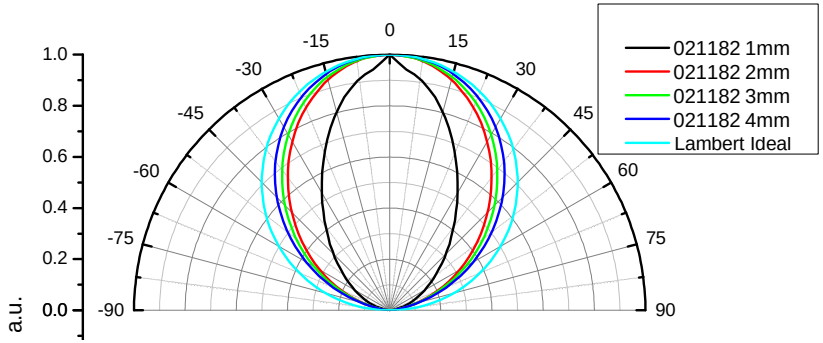
Typical Translucent Makrolon® Colors

Polar Diagrams





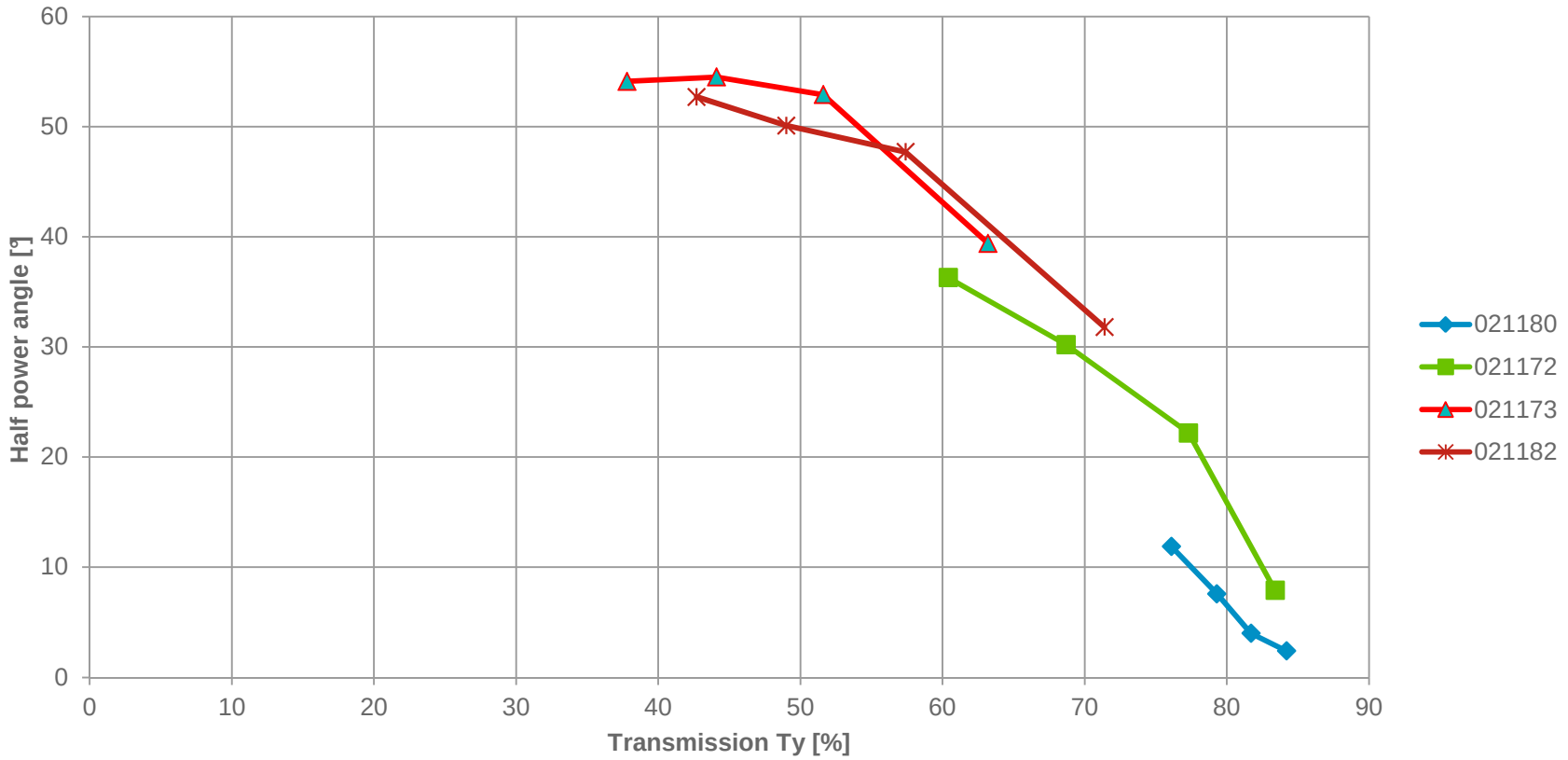




➔*Optical data are available on request for optical engineering*

Typical Translucent Makrolon® Colors

Transmission vs. Half Power Angle



➔*Optical data are available on request for optical engineering*

Diffusive Reflection

Makrolon® grades to improve the reflection of light

Advantages of Makrolon® grades for diffusive reflectors:

- High reflectivity (>94%)
- High temperature stability
- Mechanical strength

Typical Makrolon® Grades for Diffusive Reflectors

Makrolon® grade	Color number	MVR (cm3/10min)	Total reflectance (%)	UV stabilized
RW2407	012363	19	96,5	Yes
RW2407	010226	19	94,5	Yes
RW6267X	012363	19	96	Yes
RW6265X	010226	19	94	No
RW6267X	012268	19	95	Yes

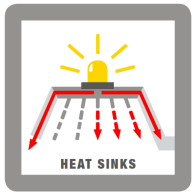
Specular Reflection

Advantages of Makrolon® grades for specular reflectors:

- High gloss surface allowing excellent reflectivity of metal layers
- Good adhesion of metallic surface to base polymer
- Best surface quality due to specially developed production cycle
- Low thermal expansion coefficient

Typical Grades for Specular Reflectors

Product grade	MVR (cm^3/10min)	Vicat temperature (℃)	CLTE parallel (10^{-4}/K)	CLTE transversal (10^{-4}/K)
Makrolon® 2405	19	143	0,65	0,65
Makrolon® GF8004	10	144	0,50	0,55
Bayblend® T90 MF-20	12	130	0,40	0,56
Apec® 1695	45	158	0,70	0,70
Apec® 2095	8	203	0,70	0,70

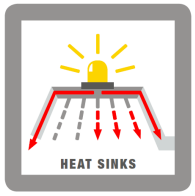


Heat Management

Optimizing the efficiency of LEDs by effective cooling

Advantages of Makrolon® grades for heat sinks:

- Reduced weight of LED light engines
- Strong heat-transferring capability
- High level of design freedom
- Cost-effective production
- Easy processing through high viscosity

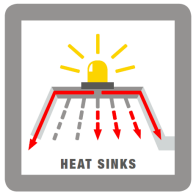


Makrolon® Grade for Heat Sinks

High thermal conductivity for very good heat transfer

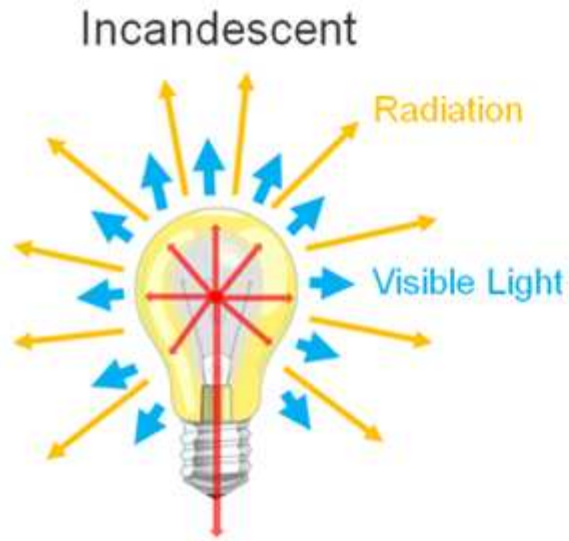
Product grade	Color number	Thermal conductivity (W/m*K)
Makrolon® TC8030	999900	20 (1) 13 (2)

(1) ISO 22007-2
(2) ASTM E 1461-01

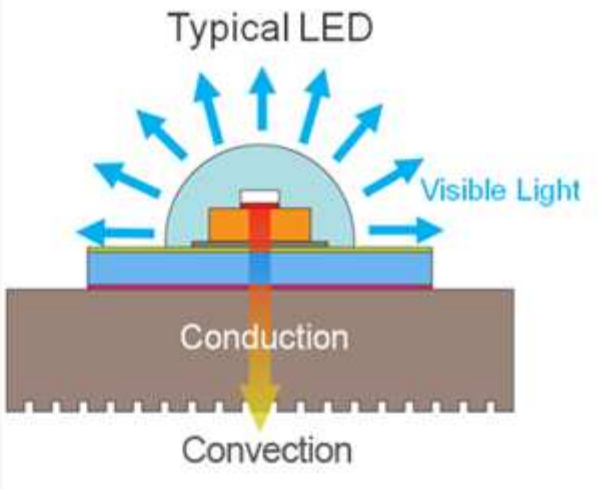


Heat Transfer

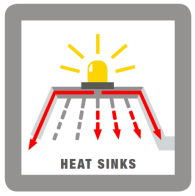
Difference between incandescent and LED light sources



Conduction + Convection

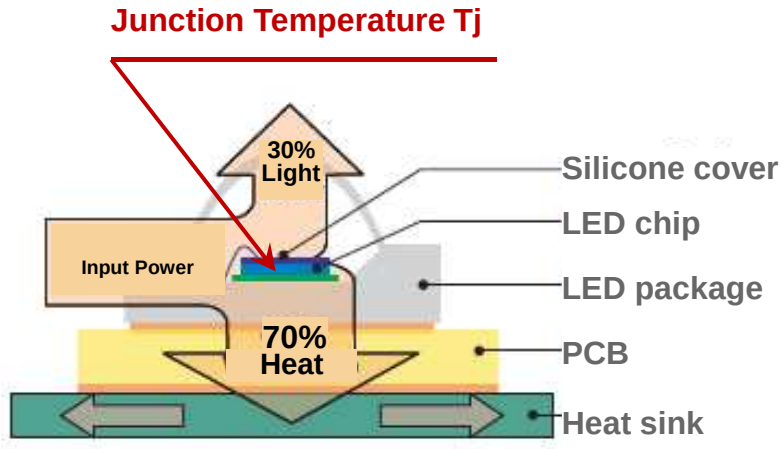


Unlike traditional light sources, LED heat dissipation depends mainly on conduction and convection. Heat produced by LED light source has to be conducted away efficiently to ensure optimal performance of a replacement lamp or luminaire



LEDs for Lighting

Convert electrical power to light and heat



- LEDs emit 70% of electrical power as heat
- Heat degrades the LED chip leading to reduced light output (degradation)
- Maximum allowed temperature for the LED package is defined by the junction temperature (Tj)

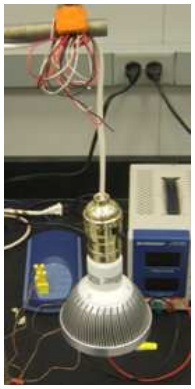
Typical values

- Maximum allowed Tj = 125℃
- Long term continuous use Tj = 85℃

The higher the junction temperature, the shorter the lifetime of the LED replacement lamp or luminaire

Makrolon® TC8030

PAR 30 – Similar Performance vs. Aluminum



Open Air Test

Enclosed in Can Light

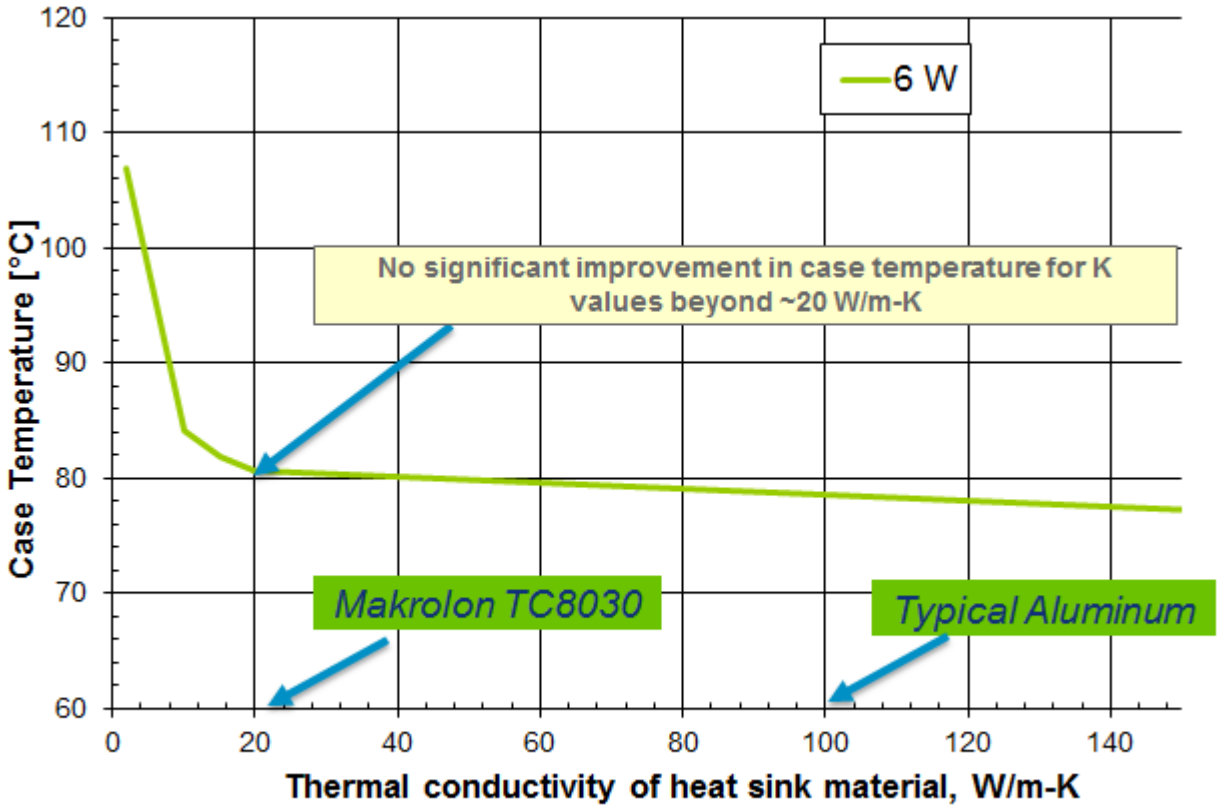
Thermocouple attached to back plate

	Enclosed Fixture		Open Air	
Heat Sink Material	Back Plate(℃)	Delta vs. Makrolon TC8030 (℃)	Back Plate (℃)	Delta vs. Makrolon TC8030 (℃)
Makrolon TC8030	**79.2**		**54.2**	
Average of 5 Purchased Aluminum Lamps	**80.2**	**+ 1.0**	**57.0**	**+ 2.8**

Makrolon TC8030 initial performance is similar to aluminum and is expected to improve over the long term from elimination of the TIM

Makrolon® TC8030

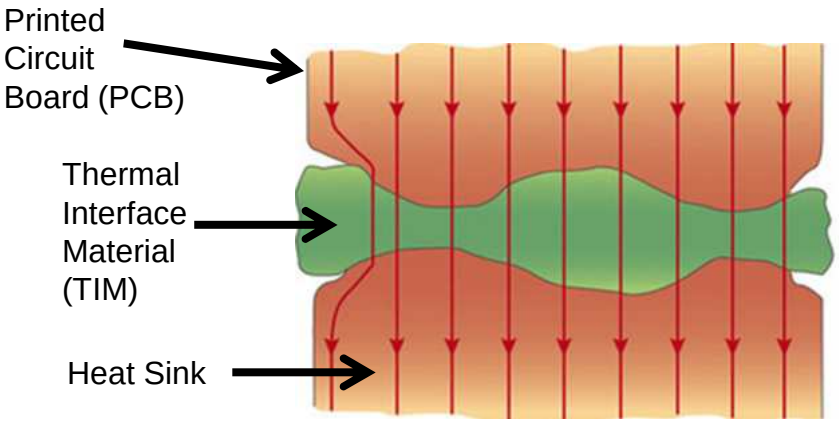
Simulation of Conductivity vs. Case Temperature



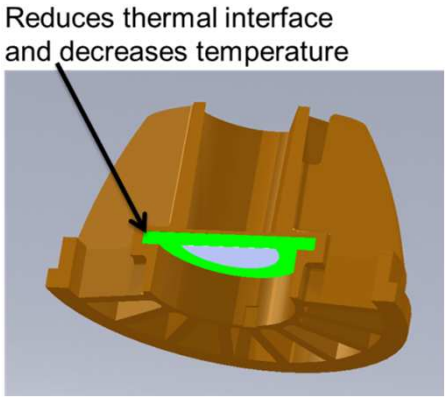
Simulation at 6W

Makrolon® TC8030

Improved Performance with Integration



Current technology with aluminum heat sink



In-Mold LED on heat sink assembly of PCB*

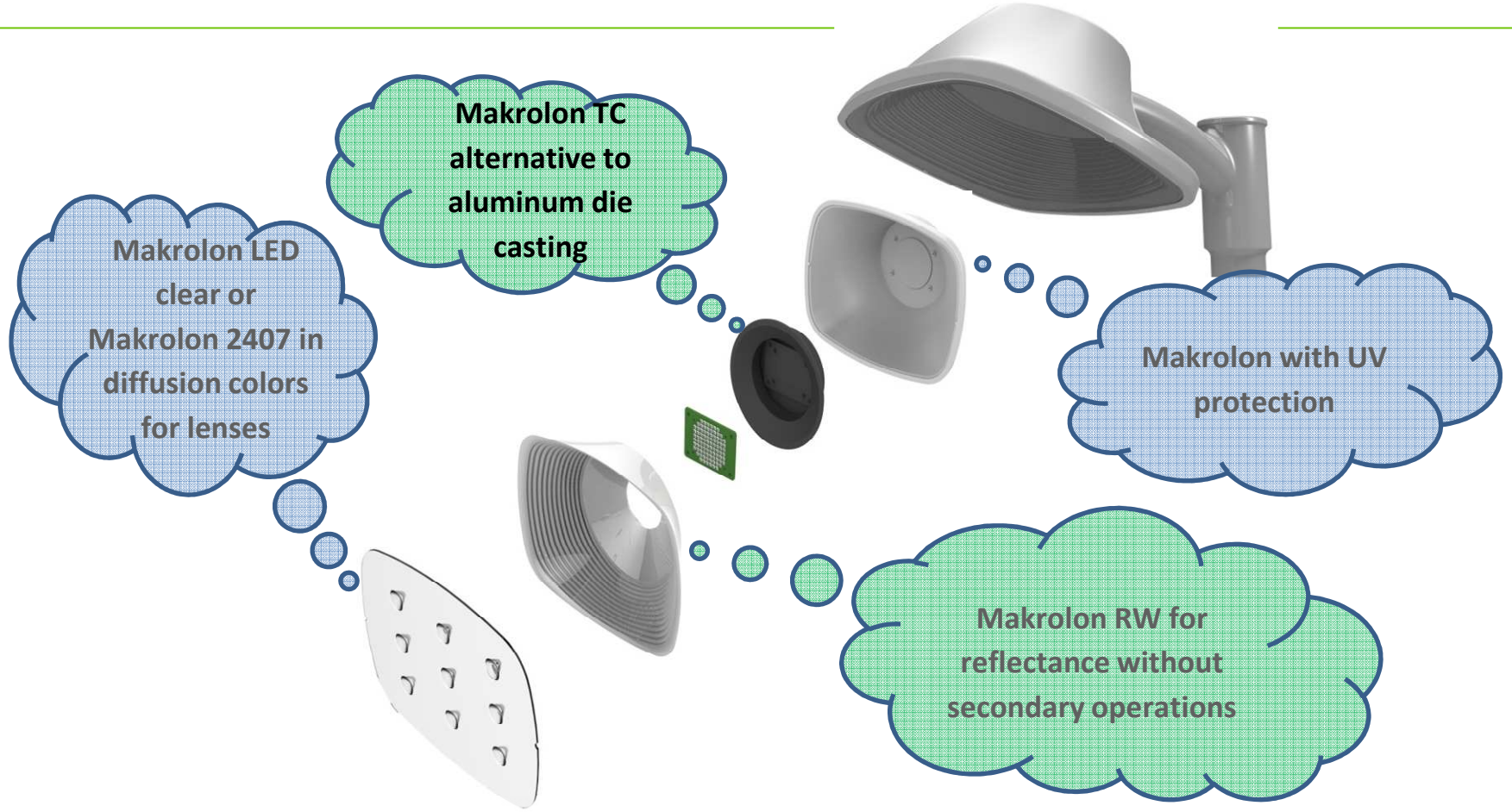
- Improved performance by elimination of thermal grease or adhesives
  - Lower thermal resistance reduces operating temperature improving LED color and life
  - Removes risk of thermal pumping of TIM over time increasing long term durability

Better quality and longer life can lead to increased sales in a highly competitive marketplace

Summary

Material Options for LED Lighting

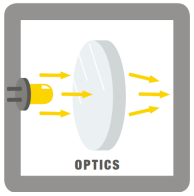
Makrolon® Products to Meet Your Design Needs



Bayer has a wide range of products for indoor and outdoor replacement lamp and luminaire components

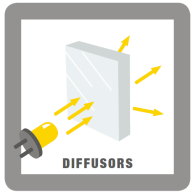
Material Options for LED Applications

Makrolon® Products to Meet Your Design Needs (selected grades!)



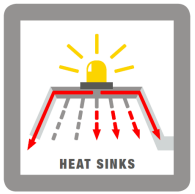
Makrolon® LED 2045 / Makrolon® LED2245 / Makrolon® LED2643
Makrolon® FR7087
Makrolon® 6717 / Makrolon® ET3113 / Makrolon® ET3127 / Makrolon® ET3227

Makrolon® LED2045 / Makrolon® LED2245



Makrolon® 2407 021180 / Makrolon® 2407 021172 / Makrolon® 2207 021177

Makrolon® RW2407 012353 / Makrolon® RW2407 012363



Makrolon® TC8030

Further Information

Homepage:
http://www.plastics.bayer.com/

eNewsletter:
http://www.materialscience-products.bayer.com/en/Newsletter/LED-Newsletter.aspx

LED brochure:
http://www.plastics.bayer.com/~/media/Product%20Center/PCS/Images/5_Library/Broschueren/LED%20Brochure/MS00069823_LED-Brosch.ashx

Contact Data

Dr. Klaus S. Reinartz
Director Marketing LED EMLA

Bayer MaterialScience AG
BU Polycarbonates
Building B207
51368 Leverkusen, Germany

Phone: +49-214-30-32403
Email: klaus.reinartz@bayer.com

Forward-Looking Statements

This presentation may contain forward-looking statements based on current assumptions and forecasts made by Bayer Group or subgroup management.

Various known and unknown risks, uncertainties and other factors could lead to material differences between the actual future results, financial situation, development or performance of the company and the estimates given here. These factors include those discussed in Bayer's public reports which are available on the Bayer website at www.bayer.com.

The company assumes no liability whatsoever to update these forward-looking statements or to conform them to future events or developments.

Science For A Better Life

Thank you!